UNIT 1 BASIC CONCEPTS OF PRESTRESSING

Structure

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1.1 INTRODUCTION

Since times immemorial, human beings have tried to develop and improve their expertise in improving things for their well-being. Development of prestressed concrete as a construction alternative has resulted in the augmentation of human capacity in the arena of design and construction of various types of articulate, aesthetic, safe and economical structures. Prestressed concrete as a construction material is a class apart from other types of conventional building materials considering the concept, construction techniques used and its advantages.

Objectives

After studying this unit, you should be able to

- understand the concept of prestressing,
- appreciate what are different forms of prestressing,
- go through the historical events, in a limited way, which led to the development of this alternate construction material, and
- be exposed to various technical terms used to represent different types of effects and techniques related to prestressing.

1.2 PRESTRESSED CONCRETE

Civil engineering structures, such as buildings, bridges, dams, towers etc. and their structural components such as beams, columns, slabs and foundations are generally subjected to various types of loads. These loads produce strains and consequently stresses develop in them. We know that if stresses exceed the material strength, the material of the structural component may crack. Cracking of a structural component may lead to a deterioration of its load bearing capacity and it may be responsible for its failure sometime.

A major part of civil engineering construction involves the use of cement concrete. Concrete has a good compressive strength and works well in those parts

of structures/structural components which are subjected to compressive stresses due to loads. But its tensile strength is very low compared to its compressive strength. Tensile strength of concrete is related with its compressive strength, which is normally represented in terms of the Grade or Characteristic compressive strength of concrete. On an average, it may be taken to be of an order of around 10% of its compressive strength.

Because of a low tensile strength and chances of consequent cracking and deterioration of load bearing capacity of structural components, we wish that either the tensile strength of concrete should be suitably enhanced (there are limits to the extent upto which it can be improved) or the tensile stresses in the structural components could be lowered.

Tensile strength of concrete may be improved by using a higher grade of concrete or by using special concretes such as fibre reinforced concrete etc. Even then, the tensile strength of concrete remains quite low and still it may not be in a position to bear high values of tensile stresses which are normally encountered in structures.

Because of this reason, concrete is reinforced with steel bars in structural components so that the tensile stresses are taken up by the reinforcement. These structural components are designed for various types of loads and appropriate amount of steel reinforcement, with suitable detailing, is provided in them. Reinforced concrete is a composite material, made of steel and concrete, in which stresses are transferred from one material to another one due to the bond between these materials.

But in some situations, even the use of reinforced concrete may not solve all the problems. For example, a very long reinforced concrete member, which may be subjected to heavy loads also, is to be provided with a big section. This makes it bulky and its increased self load further increases the external load effects. A greater amount of reinforcement may be needed in such a situation (making the member uneconomical) and even after its provision, tensile stresses in concrete may not be controlled to be lower than its tensile strength. In such situations, use of prestressed concrete may be of help.

1.3 CONCEPT

Shrink-fitting of metal tyres on the wheels of bullock carts is well known. As the hot metal tyre rings cool down, they are not able to regain their original size due to the wooden wheels. Consequently, wooden wheel parts remain together. The similar concept was used in the older times in wooden barrel construction by fitting of metal bands forcefully. Another example is the use of rubber bands to contain a sweet box. The sweet box keeps the rubber band in a stretched state and the rubber band consequently applies compression on the sweet box to keep it closed.

Prestressed concrete is a special type of concrete in which internal stresses of a suitable nature, magnitude and distribution are intentionally induced so that undesirable stresses, generated from external loads are counteracted upto a desired degree or are completely eliminated. As tensile stresses are undesirable for concrete, compressive stresses are, infact, introduced in concrete as per the requirements by the use of stretched reinforcement (which is called tendon in prestressed concrete terminology). It should be appreciated that the introduction of compressive stresses in concrete improves the apparent tensile strength of it because the tensile stresses (due to external loads), induced later, have to first

nullify these compressive stresses first. So, tensile stresses are wiped out upto the extent compressive stresses are introduced in concrete due to prestressing.

As we know, stresses from concrete to reinforcement, or vice-versa, in reinforced concrete are transferred due to bond between concrete and steel reinforcement. Considering the type of construction in terms of when the prestressing tendons are stressed and how the prestressing force is transferred into the concrete, prestressed concrete may be classified into two types :

(a) Pre-tensioned concrete, and

(b) Post-tensioned concrete.

In Pre-tensioned concrete tendons are kept stretched with suitable mechanisms and concrete is cast into the forms through which stretched tendons pass, as shown in Figure 1.1. At the start, the prestressing force is not transferred into the concrete as tendons are kept in a stretched form using jacks and abutments from both the sides. When concrete gains sufficient strength (and hence has sufficient bond strength with tendons), stretched tendons are cut from outside. The stretched length of tendons falling inside concrete remains in a stretched state, due to its bond with concrete, and the prestressing force of tendons (which is of a tensile nature) is passed into concrete in the form of a compressive force. Depending on its magnitude, this compressive force reduces or eliminates the tensile stresses, produced due to external loads, in concrete.

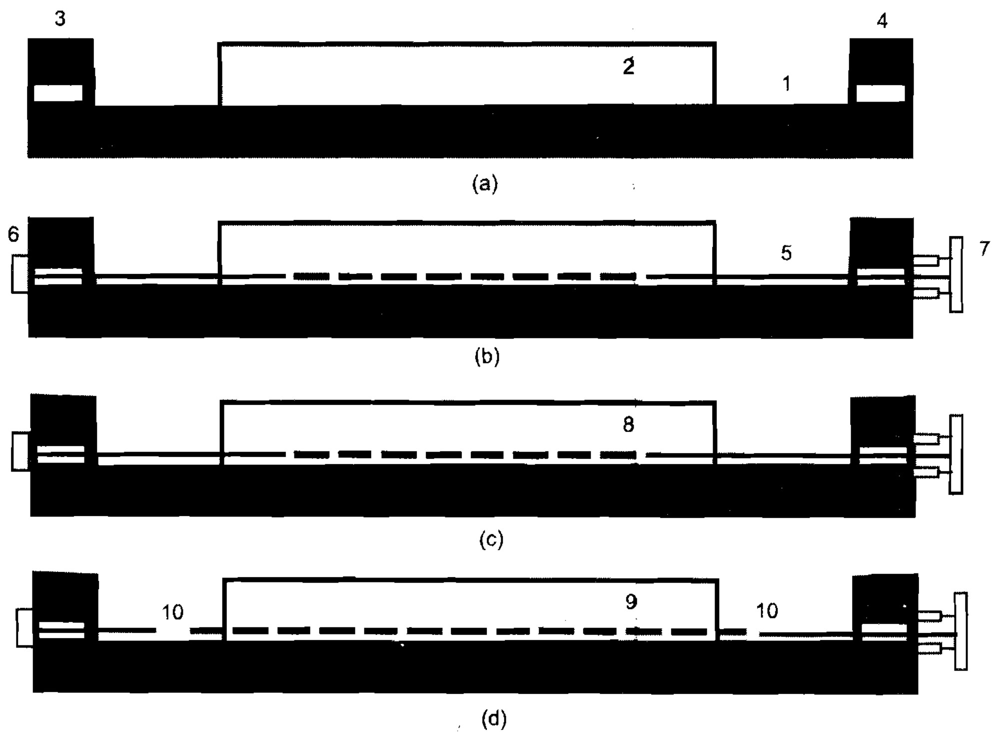


Figure 1.1 : Different Steps in pre-tensioning

(a) – concrete mould on a prestressing bed (b) – stretching of tendons passing through the concrete mould (c) – filling of concrete inside the concrete mould (d) – cutting of stretched tendons from outside after concrete gains strength.

1 – prestressing bed, 2 – empty concrete mould, 3 – abutment for anchorage of tendons, 4 – abutment for installing of jacks or other stretching devices, 5 – stretched tendons, 6 – anchored end of tendons, 7 – installed jack for stretching of tendons, 8 – concrete mould filled with concrete showing stretched tendon inside, 9 – concrete mould having concrete of sufficient strength, 10 – cutting of tendons from outside after concrete gains sufficient strength.

In Post-tensioned concrete construction, as shown in Figure 1.2, tendons are placed inside concrete and stretched after concrete has attained sufficient strength. In this form of construction, ducts are made inside concrete with the help of tubes or pipes, which are provided in the forms at the time of casting of concrete. After sufficient hardening of concrete, tendons are placed in these ducts, stretched from both ends from outside with the help of jacks or other suitable devices and anchored at the ends of the concrete member. After the anchorage of tendons, tensile force of tendons is transferred to the concrete in the form of an equal compressive force. This compressive force, upto its capacity, reduces or eliminates the tensile stresses (produced due to external loads) in concrete.

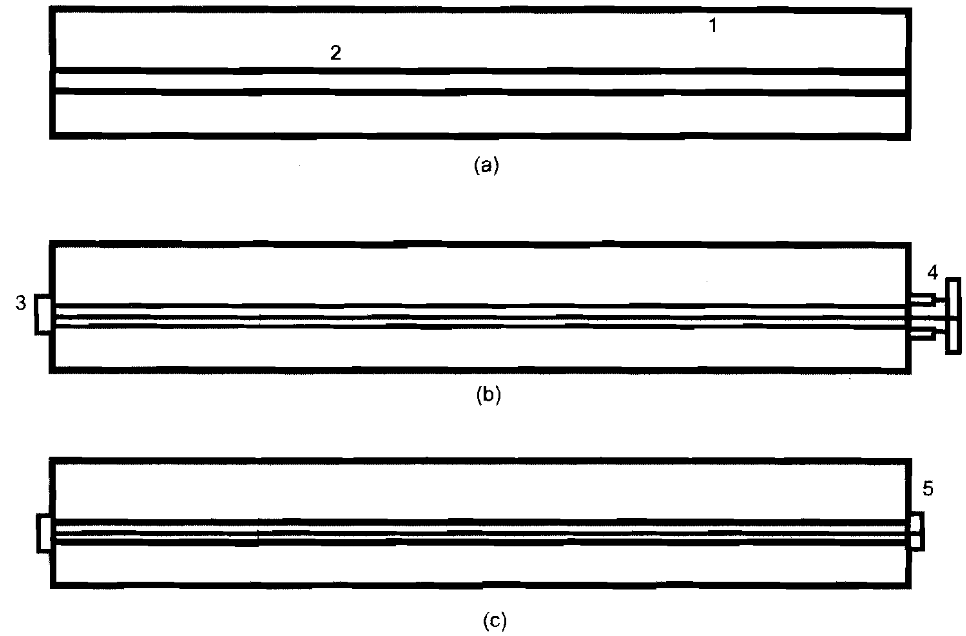


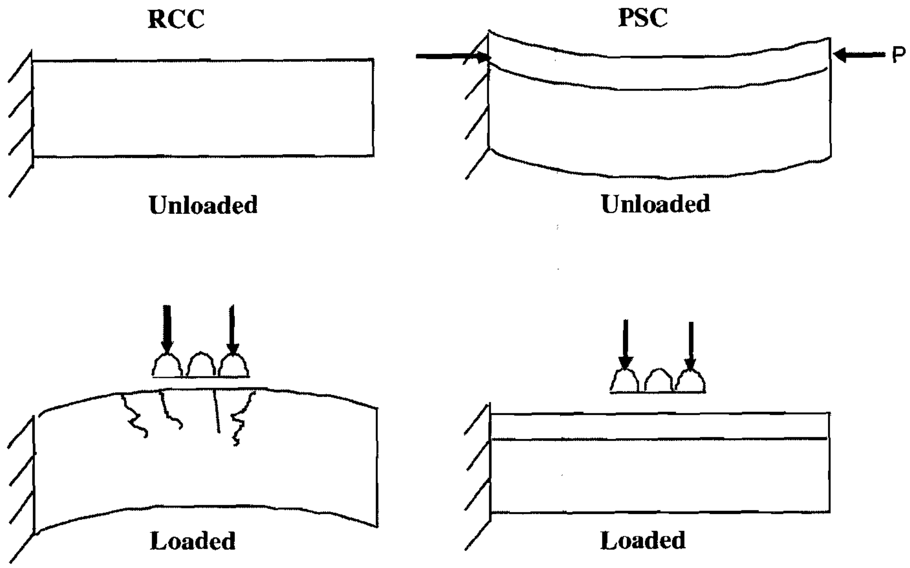
Figure 1.2 : Different Steps of Post-tensioning

(a) – casting of concrete member with a duct inside (b) – introduction of tendons inside the duct, anchorage of tendons at one end and jacking of tendons from the other end (c) – anchoring of the other end.

1 – hardened concrete member with the duct inside, 2 – the duct, 3 – anchored end of tendon at the time of stretching, 4 – stretching of tendons with the help of jacks, 5 – other anchored end of post-tensioned member after stretching operation is complete.

The effect of stretched tendons inside the concrete components is just like a stretched spring. If a spring is stretched it would like to regain its original length. If it is kept stretched, it shall keep on applying a compressive force on that material or mechanism which keeps it in a stretched condition.

Figure 1.3 shows the effect of prestress in an ordinary reinforced cantilever beam and a prestressed concrete (PSC) beam. When no load is present on both the beams, the top surface of the PSC beam is having a curvature towards the top due to the prestressing force. In this stage of no-load, the performance of an RC beam is equally good. But as loads come on both the beams, the originally flat top surface of the RC beam shall be put to a downward curvature and the top surface of it may be liable to cracking. The PSC beam behaves well even in the loaded condition as the top section is still not subjected to a large amount of tensile stresses (as the compressive prestresses neutralize some or most or all the tensile stresses produced due to external loads, applied later on).



(a) Reinforced Concrete Beam **(b) Prestressed Concrete Beam**

Figure 1.3 : Behaviour of Reinforced Concrete Beam and Prestressed Beam

In concrete structural members tensile stresses act in a longitudinal direction. This is why, stretched tendons (hereafter, called tendons) are placed in a longitudinal direction so that compressive stresses induced due to prestressing force may either reduce or eliminate these tensile stresses. In some other types of structural elements, such as water tanks and pipes, tensile stresses are produced due to hoop tension. As these tensile stresses operate along the circumference, tendons in such a situation are provided along the circumferential direction. Keeping in view the above cases, we can classify prestressing into two forms :

(a) longitudinal prestressing, and

(b) circular prestressing.

SAQ 1

(a) What are different forms of prestressing?

(b) Draw neat sketches to show how pre-tensioning is done.

1.4 HISTORICAL DEVELOPMENT

In the year 1904, Freyssinet tried to introduce prestresses in concrete to resist stresses developed due to external loads. Later, the concept of prestressing was formulated by Doehring of Germany and Jackson of United States. Mandl and Koenen were the first ones to propose a theory for modelling the behaviour of prestressed members to perform design. Notable work was done by M. Koenen and Steiner in the area of losses of prestress in prestressed members. Dischinger demonstrated the use of unbonded tendons in the year 1928 in the construction of a bridge. The first major use of prestressing in civil infrastructure in the United States was the construction of the Walnut Lane Bridge in Philadelphia in the year 1950. In the last many decades, prestressed concrete has been widely used in the construction of long span bridges, railway sleepers, shell roofs, marine structures, nuclear pressure vessels, water retaining structures, transmission towers and many other structures.

1.5 TERMINOLOGY

There are many technical terms whose understanding provides us with a good insight of the subject. Some of these terms are, indeed, general and these are used with other materials also. But some terms are specifically related to prestressed concrete. Many of such terms are explained below :

Prestressed Concrete

It is a type of concrete in which permanent internal stresses of a suitable nature, magnitude and distribution are intentionally introduced, usually by tensioned steel, to counteract, to the desired extent, the undesirable stresses caused in the member in service. Based on the type of construction, prestressed concrete may be classified as either pre-tensioned concrete or post-tensioned concrete.

These intentionally induced stresses are compressive in nature and these compressive stresses reduce or completely remove the undesirable tensile stresses which are produced due to external loads.

Tendon

It is a steel element, such as a wire, cable, bar or strand which is provided, in a stretched form, to impart prestressing force in concrete. How a tendon transfers the prestressing force in concrete decides the type of prestressed element, i.e. whether is pre-tensioned or post-tensioned.

Prestressing Force

Due to the stretching of tendons, tensile stresses develop inside tendons. Resultant prestressing force in tendons may be calculated by multiplying these tensile stresses to the cross-sectional area of tendons. When this tensile prestressing force of tendons is transferred to concrete, it produces equal compression in concrete.

Pre-tensioning

It is a method of prestressing concrete in which tendons are stretched or tensioned before concreting. In this form of construction, concrete develops a bond with the surface of stretched tendons. When sufficient bond strength is developed in concrete so as to retain stretched tendons in their tensioned form, tendons are cut from outside. The inside embedded length of tendons keeps its stretched form inside concrete due to bond and the prestressing force is maintained inside concrete.

Post-tensioning

It is a method of prestressing in which tendons are placed, inside ducts or passages provided in concrete, after concrete gains sufficient strength. Tendons are then stretched and anchored at the ends of the concrete member. The transfer mechanism of prestressing force in this form of prestressing is different from that in the case of pre-tensioning. In this form of prestressing, the prestressing force is transferred to concrete through anchorages provided at the ends - not due to bond between concrete and tendons.

Anchorage

A device used to anchor tendons at the end of a concrete member is called as an anchorage in the case of post-tensioned concrete. In the case of a

pre-tensioned concrete member, an anchorage is a device used to anchor stretched tendons during hardening of concrete.

Bonded Member

It is a concrete member in which tendons are bonded to the concrete. They may be directly bonded to the concrete as in the case of pre-tensioning or indirectly by grouting the space inside ducts in which tendons are provided in post-tensioning.

Bonded Post-tensioning

In post-tensioned construction, ducts, in which tendons are provided, are sometimes grouted after the stressing operation. Though the mechanism of transfer of prestress may still be trhough the anchorages, grouting of ducts may provide environmental protection to tendons against corrosion.

Non-bonded Prestressed Concrete

It is a method of construction in which the tendons are not bonded to the concrete. Ducts, housing the tendons, are not grouted in this case.

Full Prestressing

A prestressed concrete structural member is said to be fully prestressed if sufficient prestresses are introduced so that tensile stresses in the member, everywhere, are completely eliminated.

Limited or Partial Prestressing

It is a form of prestressing in which tensile stresses are permitted, upto a limited extent, in concrete under working loads. As the permitted tensile stresses may, under some conditions, crack the concrete, some untensioned reinforcement is also provided along with tendons.

Moderate Prestressing

In this form of prestressing, no limit is imposed on the magnitude of tensile stresses which may be produced in a concrete member under working loads. In fact, this is not prestressed concrete in the real practical sense as its behaviour is more similar to that of reinforced concrete. It is recommended that structural members falling in this type should be analyzed according to the rules and concepts, applicable to reinforced concrete structural members.

Axial Prestressing

If the centroid of cross-sectional areas of tendons is at the location of the centroid of the cross-section of the concrete member, a uniform compressive stress results over the entire cross-section of concrete. This form of prestressing – called as axial prestressing – is also known as concentric prestressing.

Eccentric Prestressing

In this form of prestressing, the centroid of cross-sectional areas of tendons is not located at the centroid of the cross-section. The distance between the centroid of the cross-section of the concrete member and the centre of gravity of tendons is called as the eccentricity of tendons. Due to this eccentricity, a moment, whose magnitude is equal to the product of the prestressing force and the eccentricity, is applied on the concrete cross-section.

Profile of Tendons

It is the shape of path of tendons along the length of the concrete member.

Non-distortional Prestressing

Concrete members deflect due to their own self weight. If prestressing force is applied in such a way that these deflections are eliminated due to the action of the prestressing force, it is called as non-distortional prestressing. In such a case, prestressing moments and self-weight moments balance each other and the concrete member is subjected to an axial force and bending moments due to externally applied loads only.

Concordant Prestressing

In this type of prestressing, tendons follow a concordant profile. The concordant profile of tendons does not change the support reactions in a statically indeterminate structure.

Uniaxial, Biaxial and Triaxial Prestressing

These terms refer to cases when the concrete is prestressed in only one direction, in two mutually perpendicular directions and in three mutually perpendicular directions respectively.

Circular Prestressing

This term refers to the case when tendon profile is provided in a round shape, such as in water tanks and pipes, etc.

Characteristic Load

The Load, which has 95 percent probability of not being exceeded during the life of a structure, is considered as characteristic load for the structure.

Characteristic Strength

The strength of a material below which not more than 5 percent results are expected to fall is considered as the characteristic strength of the material.

Supplementary or Untensioned Reinforcement

It is that reinforcement, provided in prestressed concrete member, which is not provided in a stretched condition like tendons.

Transfer

It is the act of transferring the stress in prestressing tendons to the concrete member. In the case of pre-tensioned concrete elements, this stage comes when jacks (which stretch tendons till concrete gains sufficient strength) are released. In the case of post-tensioned concrete members, this stage comes when stretched tendons are anchored at the ends of the concrete member.

Initial Prestress

From the transfer stage, tensile stresses in tendons apply compressive stresses in concrete. The initial value of these stresses (in tendons or in concrete) is called initial prestress (in tendons or in concrete, whichever is considered).

Initial Tension

The maximum stress induced in the prestressing tendon at the time of the stressing operation is known as initial tension in tendons. The initial tension is usually more than the initial prestress as during the transfer stage some instant losses of prestress take place.

Loss of Prestress

At the transfer stage, tendons produce compressive stresses in concrete. Sooner or later, the magnitude of these stresses experiences a reduction due to some reasons. This reduction in the prestressing force or prestresses is called as loss of prestress.

Final Prestress

The stress which exists after all losses of prestress have occurred substantially is known as final prestress. This may be calculated by subtracting losses of prestress from the initial prestress.

Final Tension

The tension in tendons after losses of prestress have taken place is called as final tension. Final tension is taken to be corresponding to the stage of the final prestress.

Elastic Shortening of Concrete

At the transfer stage, compressive prestressing force is transferred to the concrete. Due to this compressive force, concrete is subjected to an instant shortening of length in the direction of this force depending on the magnitude of prestressing force. This is called as elastic shortening of concrete.

Loss of Prestress due to Elastic Shortening of Concrete

Due to elastic shortening of concrete, tendons are able to reduce their stretched length to the same extent upto which the reduction of length occurs in concrete. Due to this, strains in tendons (and hence stresses in tendons) are reduced, causing loss of prestress. This loss is known as loss of prestress due to elastic shortening of concrete.

Creep

Creep is a phenomenon due to which strains in a material increase with time under constant stresses.

Creep Coefficient

This is the ratio of creep strain to elastic strain in a material.

Loss of Prestress due to Creep in Concrete

Due to the phenomenon of creep, compressive prestress induced strains in concrete increase. Because of it, strains of tendons decrease and consequently loss of prestress takes place in tendons. This is called as loss of prestress due to creep in concrete.

Loss of Prestress due to Shrinkage of Concrete

It is the loss of prestress due to shrinkage of concrete, which takes place in the initial stage of hardening of concrete. Due to shrinkage of concrete, compressive strains in concrete increase (so the tensile strains in tendons decrease to the same extent) and consequently there is a loss of prestress in the concrete member.

Relaxation of Steel

If the strain in steel is kept constant, it is seen that stresses in it reduce with time. It is called as relaxation of steel. Tendons in prestressed concrete are provided with a particular strain (due to stretching) and this strain is kept constant inside concrete. Due to relaxation of steel, stresses in tendons

reduce with time, leading to what is called as 'loss of prestress due to relaxation of steel'. The relaxation losses in prestressing steels vary with type of steel, initial prestress, age and temperature, etc.

Slip in Anchorage

In the case of post-tensioned concrete, when the tendons are anchored at the ends of concrete members, a slip of tendons takes place. Sometimes, anchorages settle down inside concrete ends by a certain distance. Both of these are considered as slip in anchorage. This is one of the reasons of loss of prestress in post-tensioned concrete members.

Transmission Length

It is the distance required at the end of a concrete member for developing the maximum tendon stress by bond.

End Zone

It is the length of a post-tensioned concrete member, at the end, which is required to get a distribution of prestress over the whole of the cross-section of the concrete member. At the ends of post-tensioned concrete members, anchorages apply the prestressing force on only a part of the cross-section of concrete. As we move from an end towards the middle of the concrete member, the distribution of longitudinal prestresses occupies more and more cross-sectional area. The zone which lies between an end of the member and the section where full cross-sectional area of concrete is subjected to longitudinal prestress is known as end zone.

Bursting Tensile Forces

These are tensile forces produced due to concentrated longitudinally applied prestressing forces in the end zone of a post-tensioned concrete member. These are directed in a lateral direction and may cause bursting of concrete in a lateral direction due to tension. To contain these forces, lateral reinforcement is provided in the end zone of post-tensioned concrete members.

Limit State

The acceptable limit for the safety and serviceability requirements, before failure occurs, is called as a 'limit state'.

Limit States of Collapse

Those limit states which point out the failure or collapse of a structure based on certain critical conditions are called as limit states of collapse. Certain conditions such as rupture of critical sections due to bending, shear, torsion, compression and tension, buckling due to elastic or plastic instability (including the effect of sway wherever appropriate) and overturning, etc. are considered in the determination of limit states of collapse.

Limit States of Serviceability

These are those limit states which point out to the inability of a structure or a structural component in functioning properly as per the intended requirements. Normally, effects of deflection, cracking, vibrations and maximum compression are considered in the determination of limit states of serviceability.

IS : 1343-1980

It is the standard Indian code of practice which gives guidelines and specifications for analysis and design of prestressed concrete members. It is published by Bureau of Indian Standards, New Delhi.

Type 1 Prestressed Concrete

It is the prestressed concrete in which no tensile stresses are allowed.

Type 2 Prestressed Concrete

It is the prestressed concrete in which tensile stresses are allowed but no visible cracking is permitted.

Type 3 Prestressed Concrete

It is the prestressed concrete in which cracking is allowed but it should not affect the appearance or durability of the structure. The acceptable limits of cracking would vary with the type of structure and environment and would vary between wide limits. For such members, as a rough guide, the surface width of cracks should not, in general, exceed 0.1 mm for members exposed to a particularly aggressive environment (which are listed in Appendix 'A' of IS : 1343-1980) and not exceed 0.2 mm for all other members.

Short Term Effects

These are various types of effects produced, nearly instantaneously, due to the application of external loads on structures. An example in this respect may be the deflections produced due to external loads in a concrete structure. Effects produced due to long term effects such as creep and shrinkage are not considered when considering short term effects.

Long Term Effects

Long term effects of loads on structures consider all the effects including creep and shrinkage.

Column or Strut

It is a compression member of rectangular section, the effective length of which exceeds three times of its least lateral dimension.

Short Column

It is a column of rectangular section, the effective length of which does not exceed 12 times of its least lateral dimension.

Slender Column

It is a column of rectangular section, the effective length of which exceeds 12 times of its least lateral dimension.

Cracking Load

The load on the structural member at the time of the initiation of first visible crack in concrete is known as cracking load for the member.

Proof Stress

It is the tensile stress in steel which produces a residual strain of 0.2 percent of the original gauge length on unloading.

Degree of Prestressing

It is a measure of the magnitude of the prestressing force related to the resultant stress occurring in the structural member at the working load.

Debonding of Tendons

It is the process of preventing the bond formation between the tendons and concrete so that tendons remain in an unbonded condition.

1.6 NEED FOR HIGH STRENGTH STEEL AND CONCRETE

In prestressed concrete construction, tendons have a small area of cross-section compared to the cross-sectional area of concrete. To induce compressive stresses of some magnitude in concrete, comparatively very high values of tensile stresses are required to be introduced in steel tendons (using $A_c \sigma_c = A_s \sigma_s$, where A_c, A_s, σ_c and σ_s are cross-sectional areas and stresses in concrete and tendons respectively).

In pre-tensioned concrete, the tendon stresses are transferred to concrete by virtue of bond of concrete to the surface of steel tendons. As mentioned earlier, the bond strength of concrete with steel depends on the grade or characteristic strength of concrete. So to transfer a high value of force from tendons to concrete it is essential to have concrete of a high strength.

Further, a high strength concrete is less liable to elastic shortening, shrinkage and creep and so the losses of prestress may be of a lower magnitude.

There is another aspect to why we need a high strength concrete in prestressing. Prestressed concrete is subjected to high values of compressive, tensile, shear, bond and bearing stresses. In the case of post-tensioned concrete, anchorages occupy a little cross-sectional area of concrete at the ends. Through these small areas, the prestressing force of a high magnitude is transferred to the concrete member. If the strength of concrete is not adequate, the anchorages may locally damage the end portion of concrete member and may punch inside concrete. If this happens, a major portion of tendon stresses may get lost.

The use of high-strength concrete results in a reduction in the cross-sectional dimensions of prestressed concrete elements. Due to this, the self weight of the component and hence bending moments and other forces get reduced. Longer spans become technically and economically feasible.

The material of steel tendons also must be of a high strength. Tendons should possess required material and geometrical properties so that a desired degree of prestress could be produced in the material. It should remain elastic utpo to high stress levels. It should have a high value of elastic modulus in order to contribute to the stiffness of the prestressed structural element. It should be subjected to low creep and relaxation losses at the stress levels normally encountered in prestressing, especially at high temperatures.

Recognising the losses of prestress which take place after the prestressing of concrete structural elements, it is to be appreciated that prestresses of an order of 100 to 250 N/mm^2 is generally lost due to various reasons. If the losses of stresses are to be a small portion of the initially induced prestresses, the tendon material should be able to sustain a very high stress – say about 1200 to 2000 N/mm^2. This high value of strength may not be available in mild steel and high strength steel which is used in reinforced cement concrete. This fact clearly emphasises the necessity of having tendon steel of a high strength grade.

SAQ 2

Why high strength materials are needed in the construction of prestressed concrete components?

1.7 ADVANTAGES AND APPLICATIONS OF PRESTRESSED CONCRETE

In prestressed concrete structures, concrete is subjected to prestresses of a compressive nature. In a direction along the profile of the tendons, concrete is more or less in a confined state until it cracks under the action of loads. Due to this confinement effect, prestressed concrete members possess improved resistance to shearing forces.

Type 1 or fully prestressed concrete structures are free from tensile stresses under working loads. This fact makes them free from cracks in the working range of loads unlike reinforced concrete members which may be subjected to cracking. As the prestressed concrete has either no cracks or has only cracks of low width, it is more protected against aggressive environmental conditions, making it more durable.

Due to the effect of compressive stresses, concrete is subjected to lesser values of principal tensile stresses. The use of curved cables, especially in long span members, helps to reduce the shear forces at the support sections. The use of curved cables (by changing the eccentricity of tendons) may counteract the effects of a permanent dead load in a better way, considering the load balancing aspects (explained in a later chapter) of a prestressing force.

The use of prestressed concrete, having materials of higher strengths, may substantially reduce the sectional areas of members resulting in the possibility of use of lighter and slender members. This means savings in the quantity of materials used. Cost-wise, this fact may not point necessarily towards the economy as the savings in the quantity of materials may be offset by the higher costs of better grade materials, need of anchorages and other hardware required in the case of prestressed concrete construction. Even then, self loads of members are reduced to a considerable extent and this may have some effect on the design of foundations.

Prestressing of concrete enhances the ability of the material for energy absorption under impact loads as well as under fatigue conditions. That is why, these are preferred in dynamic loading conditions. They give a better performance in the case of machine foundations, bridges and railway sleepers, all of which are subjected to dynamic forces. Prestressed concrete members are stiffer than other conventional materials of construction such as reinforced concrete. This gives them an edge in terms of lesser deflections and an improved resistance to higher loads which may sometimes be occasionally applied, as the cracks formed under such loads close up, due to the presence of prestress, once these loads are removed.

Apart from the above advantages offered by prestressed concrete, prestressed concrete members are more pleasing and have more aesthetic appeal due to their slender size and shape.

The basic advantage of the use of prestressed concrete lies in its high strength to weight ratio and its strength to cost ratio in comparison to other conventional building materials such as reinforced concrete. Prestressed concrete is a highly versatile material and has a high resistance against fire and corrosion of reinforcement.

Figures 1.4 and 1.5 show how box girder shaped pre-cast segmental units may be used in the construction of a post-tensioned bridge span. The precast units are provided with holes at appropriate places so that these may be linked to make a duct for housing tendons when these pre-cast units are joined. Figure 1.6 shows a location in the Delhi metro rail network and such pre-cast units are visible.

Figure 1.7 shows one such pre-cast segmental unit along-with its reinforcement. Duct holes for tendons are clearly visible in the unit.

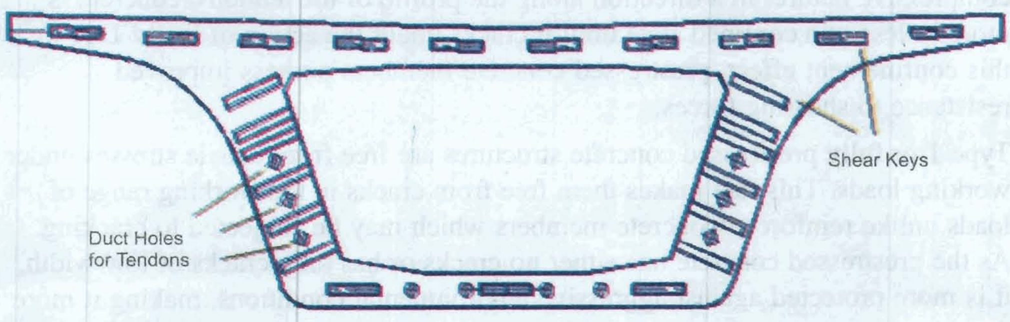


Figure 1.4 : Box Girder Shaped Pre-cast Segmental Unit

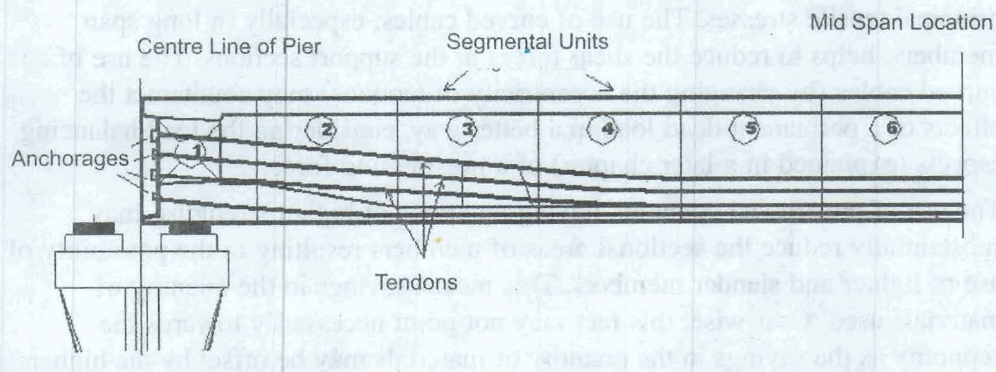


Figure 1.5 : Assembly of Segmental Units in Post-tensioned Bridge Span

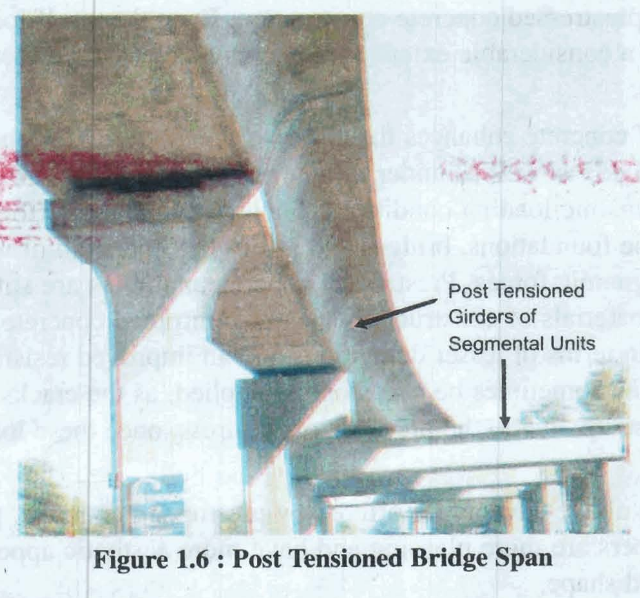


Figure 1.6 : Post Tensioned Bridge Span

Figure 1.7 : Pre-cast Segmental Unit along with its Reinforcement

Because of many salient advantages offered by prestressed concrete, it is widely used in the construction of precast concrete building components such as hollow cored and ribbed slabs, single and double T-shaped units and channel sections for roofing, long span I and box shaped bridge girders, long span folded plate roofs, aircraft hangers, nuclear containment vessels, pavements, railway sleepers, poles, piles, towers and masts.

SAQ 3

(a) What are the advantages of prestressed concrete?

(b) What are various applications of prestressed concrete?

1.8 SUMMARY

In this unit, the basic concept of prestressing has been presented. Though the basic materials (i.e. concrete and steel) may remain the same, as in reinforced cement concrete, prestressed concrete as a material is a class apart from other materials. Types of prestressed concrete, its historical development, procedures involved in the construction of different types and various terms related to it are presented in short. Many of the terms presented in this unit shall be used in later units and the students may have to turn back to this unit many times. Why we need high strength constituent materials in the case of prestressed concrete as also various advantages and disadvantages have been presented.

The student shall do well to explore related information in other text books and the internet. In this connection, case studies of construction where this material has been used shall offer a deep insight into the use of prestressed concrete.

1.9 ANSWERS TO SAQs

Please refer the preceding text for all the Answers to SAQs.